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Chan

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(54) **DETECTOR FOR PLASTIC OPTICAL FIBER NETWORKS**

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- (*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1093 days.

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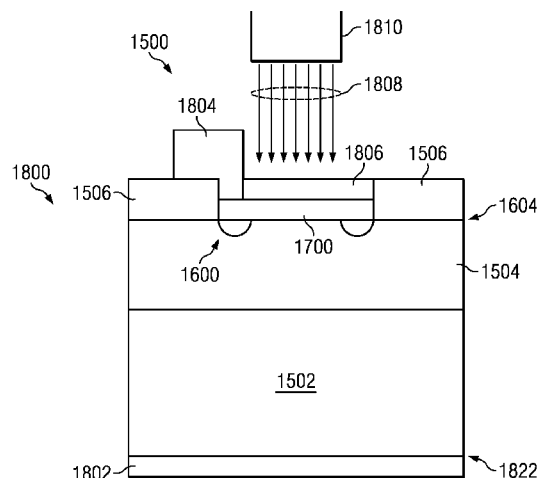
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USPC 257/116, 431–437, 449, 450–457, 257/E29.336, E29.338, 463, E31.065; 438/69, 92

(57) **ABSTRACT**

An apparatus comprises a substrate having a type of conductivity, an intrinsic region above the substrate, and a metal layer on a portion of the surface of the intrinsic region. The intrinsic region has a surface. The metal layer may have a thickness that is configured to allow a plurality of photons to pass through the metal layer into the intrinsic region and form a rectifying contact with the intrinsic region.

See application file for complete search history.

31 Claims, 12 Drawing Sheets



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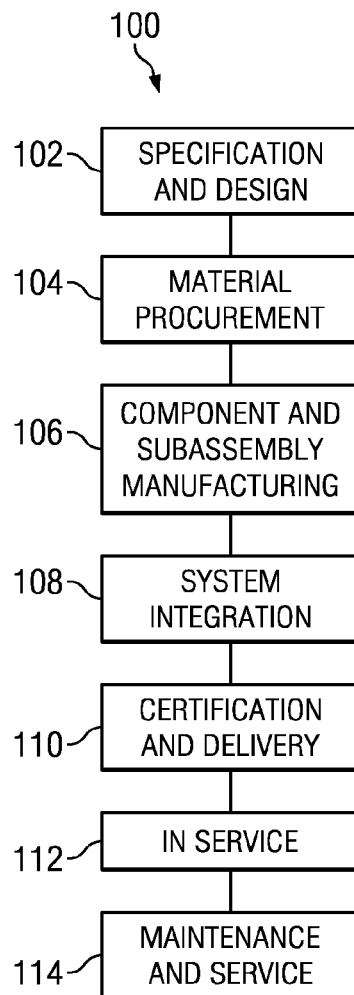
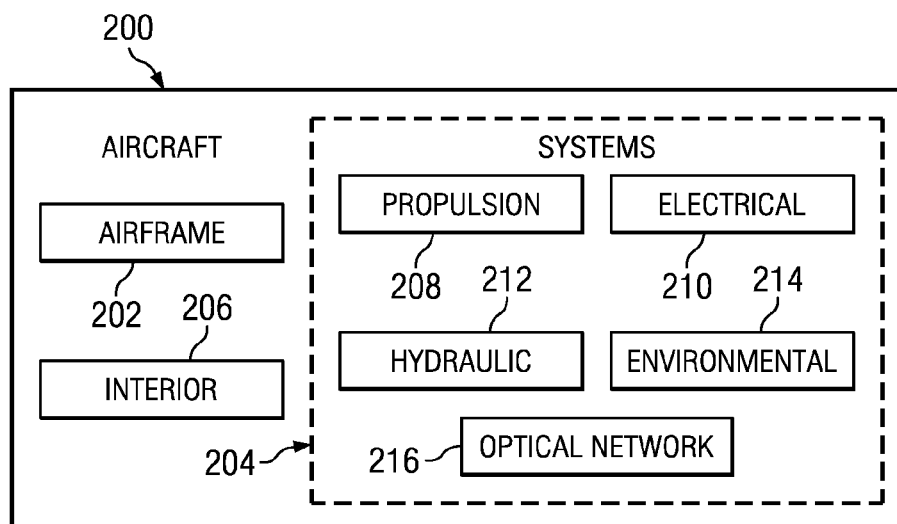
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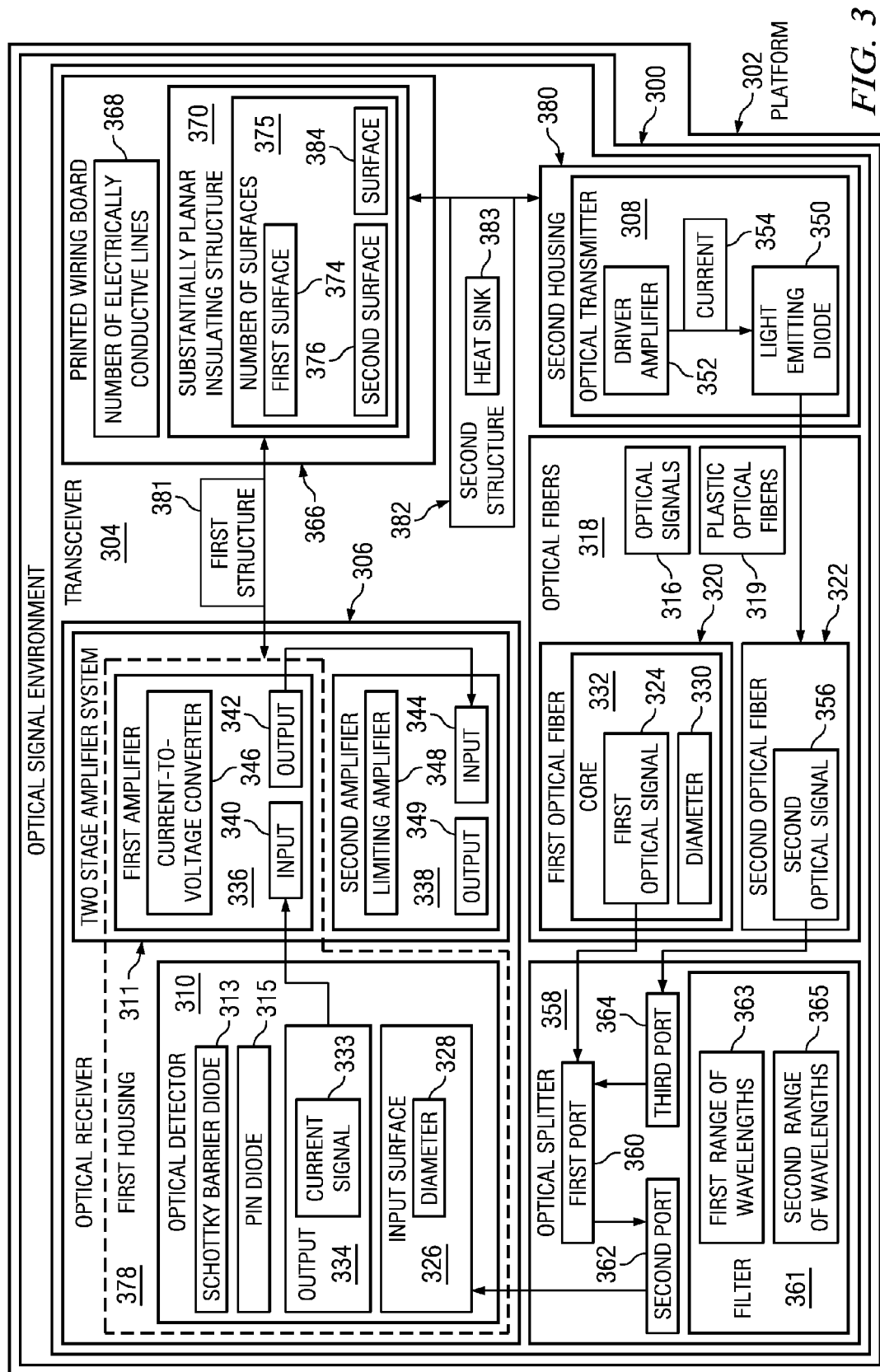
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*FIG. 1**FIG. 2*



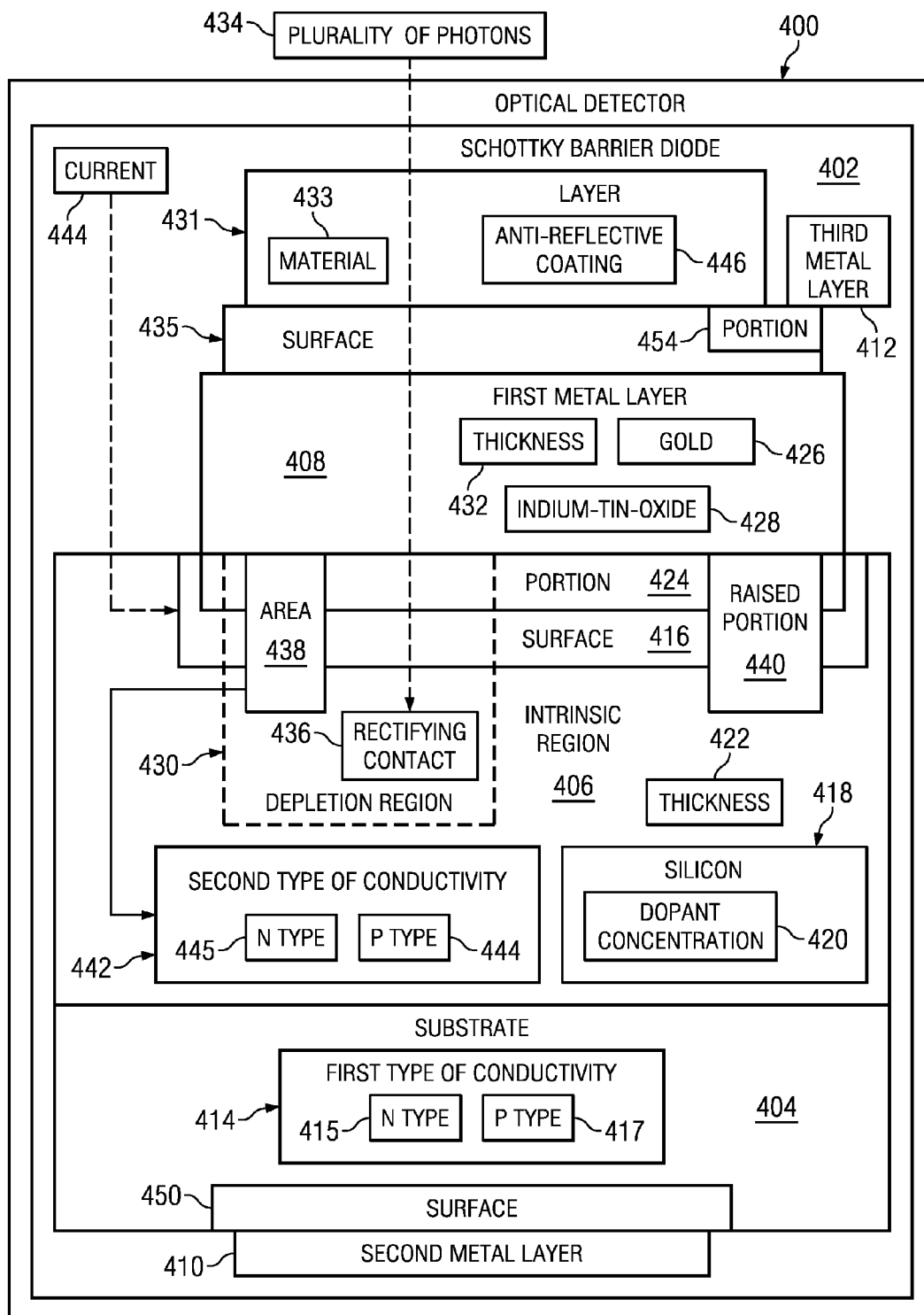
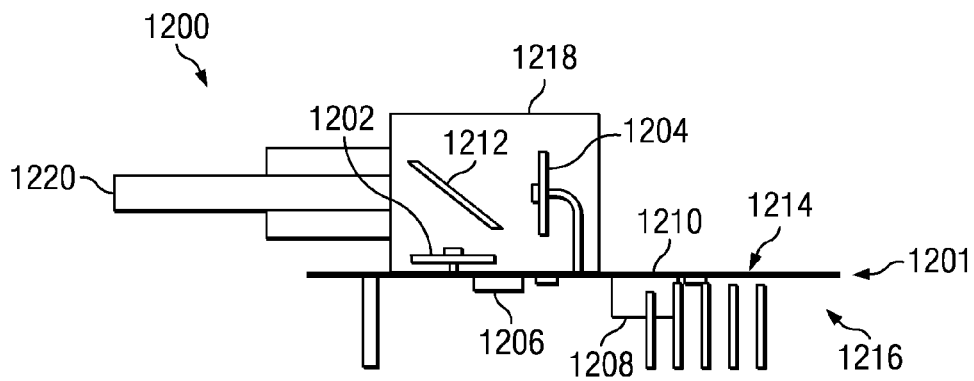
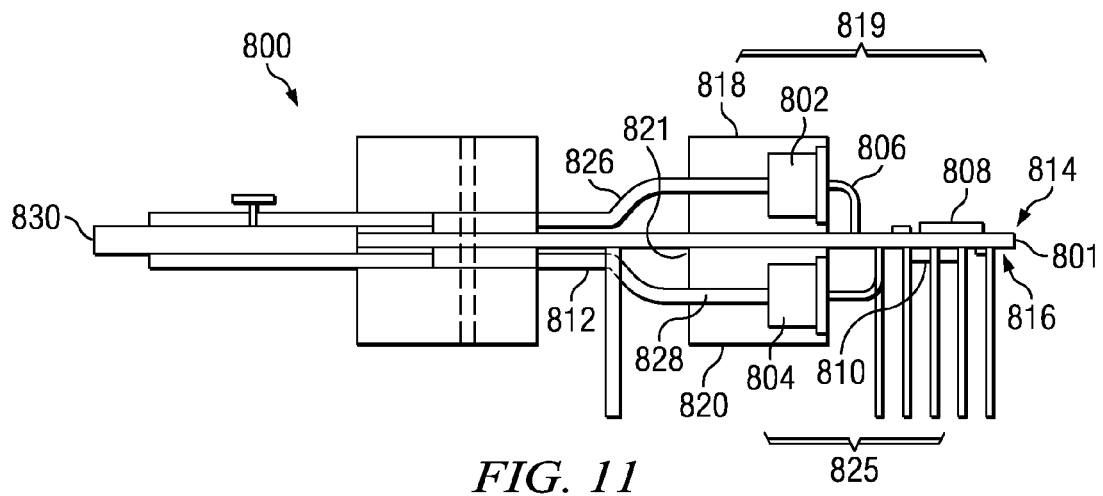
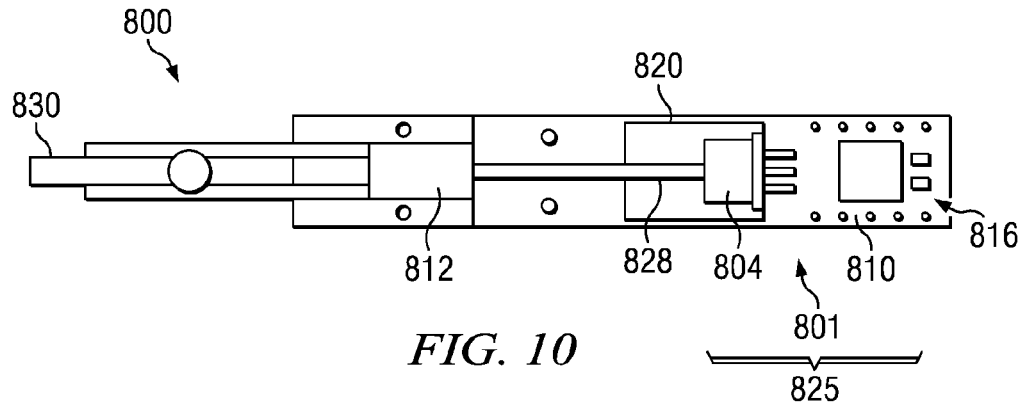


FIG. 4

FIG. 6





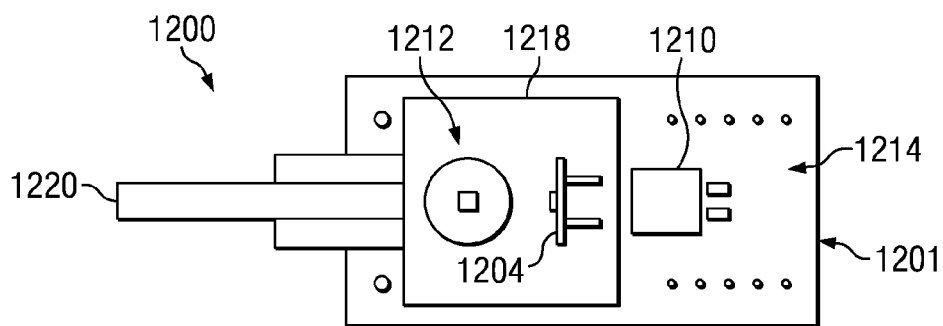


FIG. 13

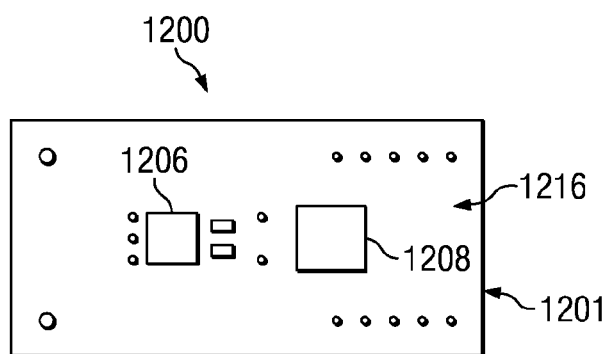


FIG. 14

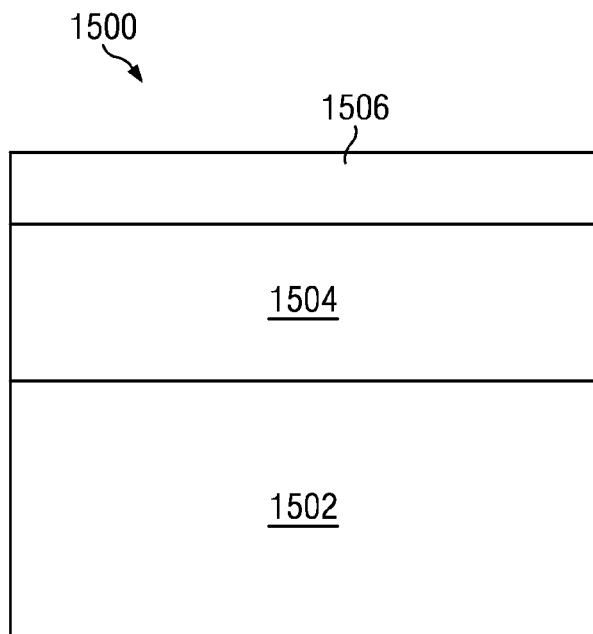


FIG. 15

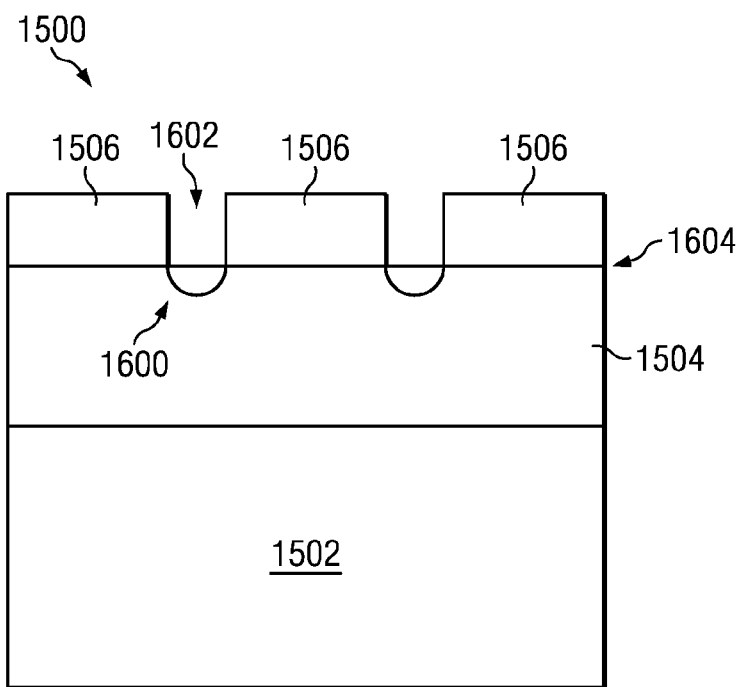


FIG. 16

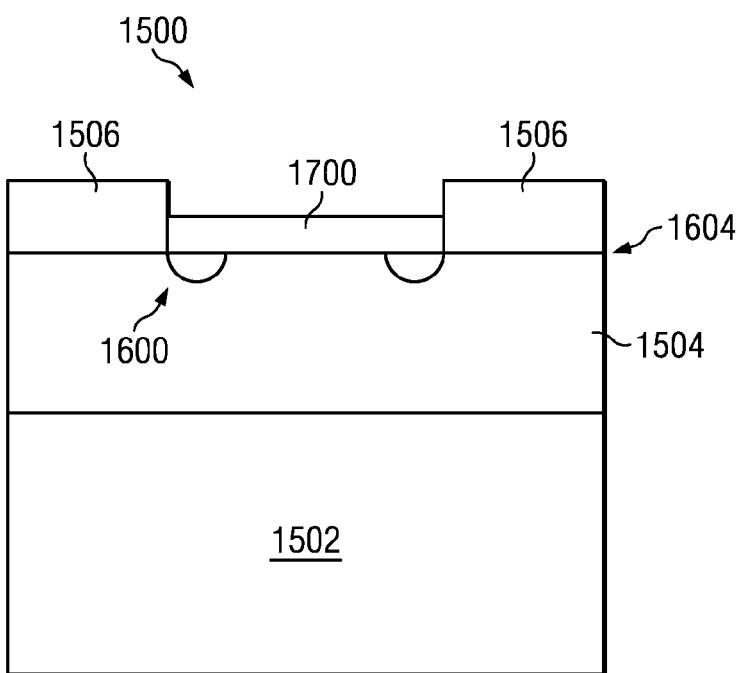


FIG. 17

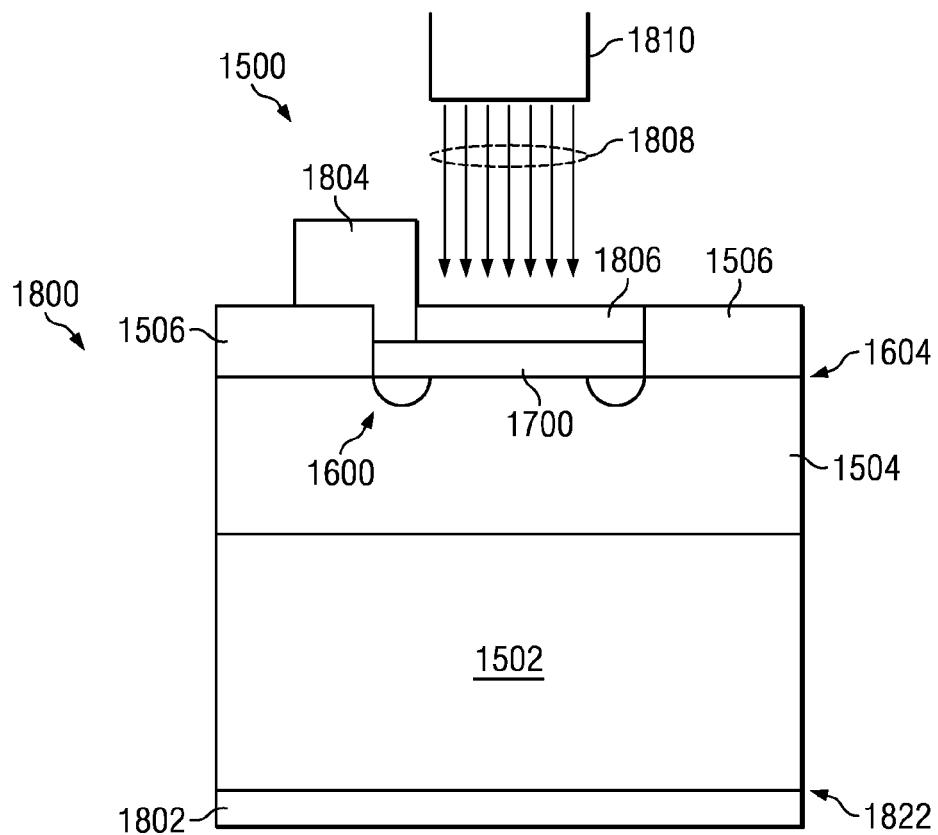


FIG. 18

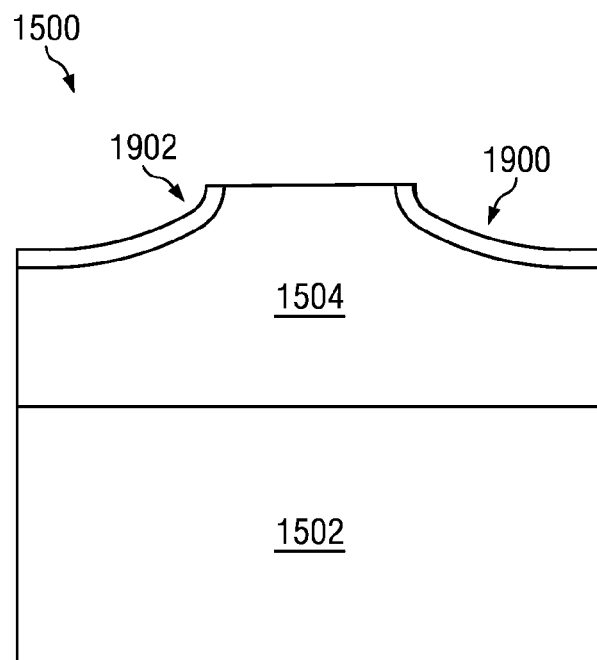


FIG. 19

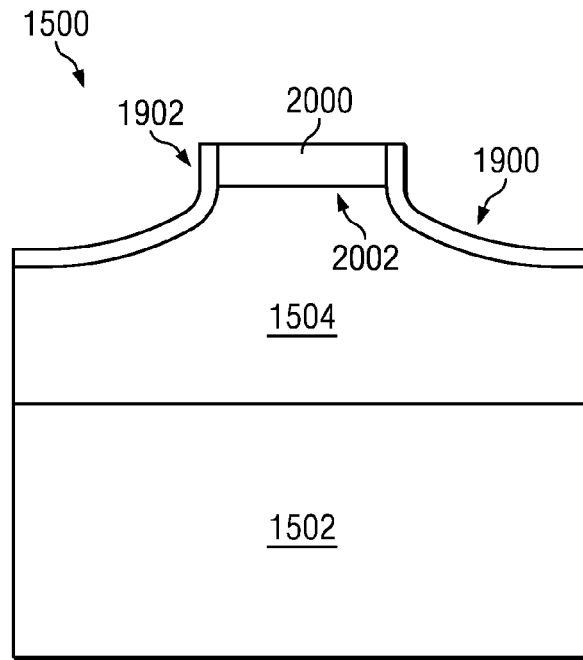


FIG. 20

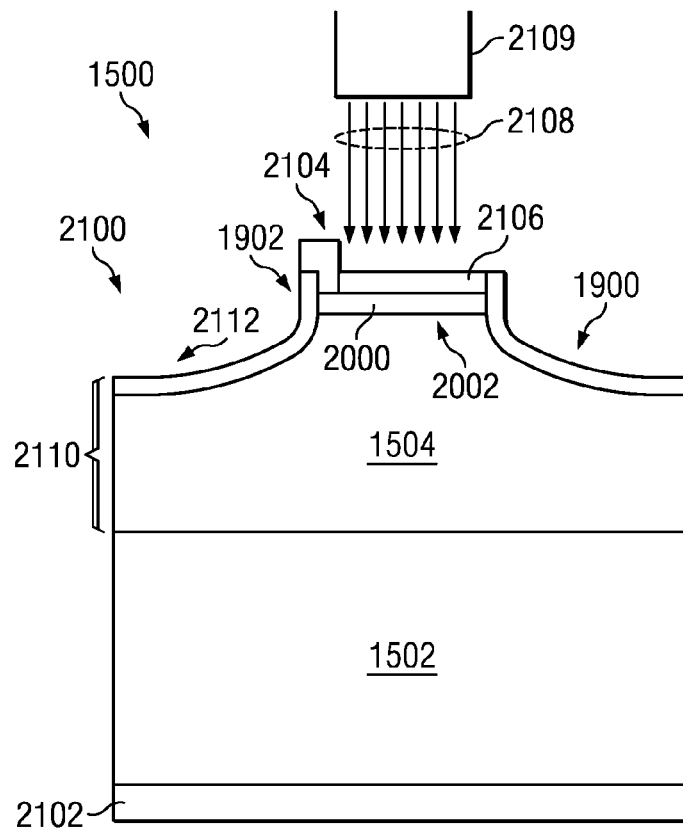
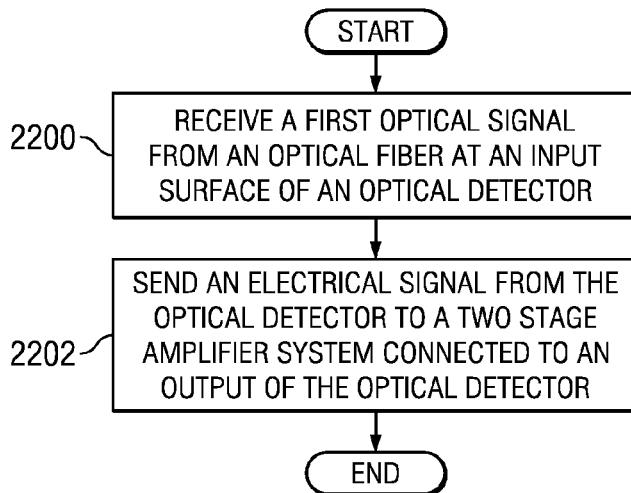
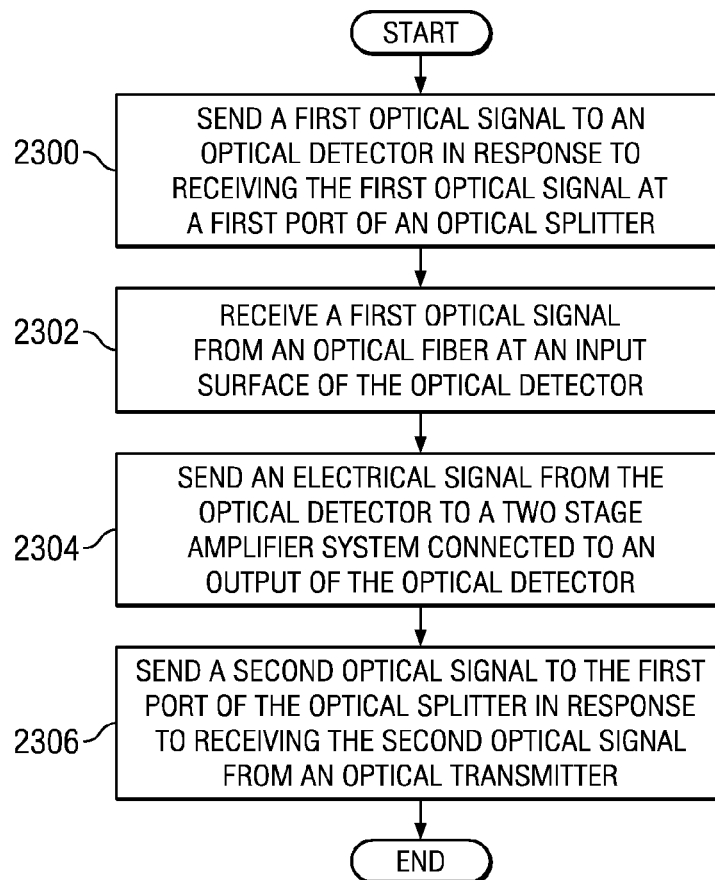
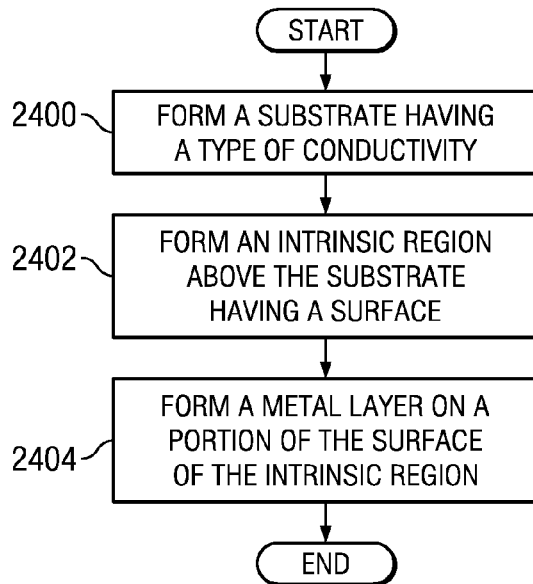
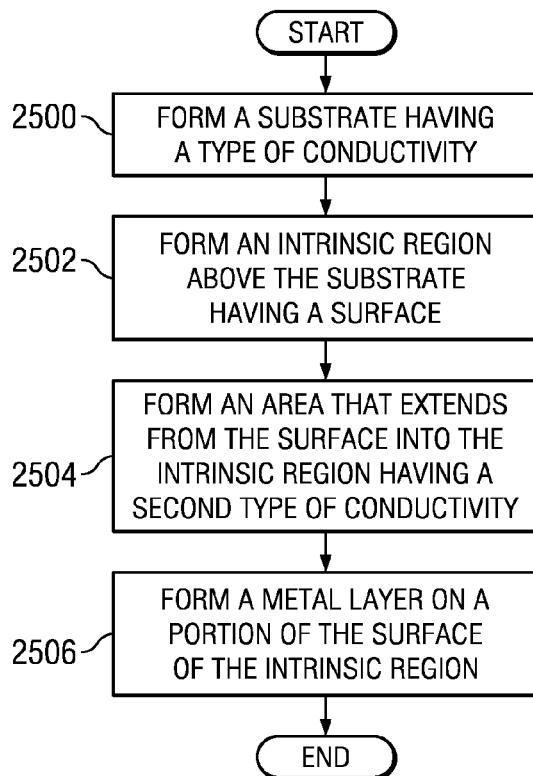
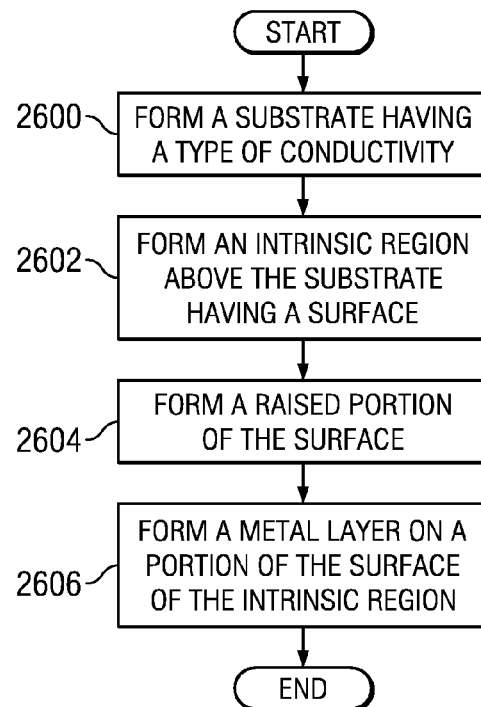


FIG. 21

*FIG. 22**FIG. 23*

*FIG. 24**FIG. 25**FIG. 26*

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DETECTOR FOR PLASTIC OPTICAL FIBER NETWORKS**CROSS REFERENCE TO RELATED APPLICATION**

The present disclosure is related to the following patent application: entitled "Transceiver for Plastic Optical Fiber Networks", Ser. No. 12/612,968, filed even date hereof, assigned to the same assignee, and incorporated herein by reference.

BACKGROUND INFORMATION**1. Field**

The present disclosure relates generally to fiber optics and, in particular, to a method and apparatus for transmitting optical signals over optical fibers. Still more particularly, the present disclosure relates to a method and apparatus for a detector used with plastic optical fibers in a network in an aircraft.

2. Background

Information may be transmitted in the form of signals using a number of different types of mediums. Optical fibers are one type of medium for transmitting signals in networks. In particular, optical fibers may be used to transmit signals in long-distance communications networks. Optical fibers allow the transmission of signals over greater distances and at higher bandwidths as compared to other types of mediums, such as, for example, metal wires. Signals travel through optical fibers with reduced power loss as compared to signals traveling through metal wires. Further, optical fibers are also immune to electromagnetic interference.

The materials used in optical fibers are typically selected from one of glass and plastic. The physical properties of glass make the use of glass optical fibers (GOFs) in optical networks desirable in many cases. For example, glass optical fibers experience less signal loss over a given distance than plastic optical fiber (POF). Networks using glass optical fibers are desirable for long distance communication networks. Signal loss becomes a greater concern as the distance over which an optical signal travels increases.

For example, optical signals sent over a network using glass optical fibers operate at the near infra-red (IR) wavelength range of about 1300 nanometers to 1550 nanometers. At these wavelengths, glass optical fibers experience a loss of about 0.2 decibels per kilometer. In contrast, optical signals sent through plastic optical fibers operate in the red wavelength range of about 650 nanometers. At this wavelength, optical signals through plastic optical fibers experience a loss of about 150 decibels per kilometer. Thus, the loss that occurs with optical signals traveling through plastic optical fibers is over two orders of magnitude higher than glass optical fiber signal loss.

Despite these advantages, the use of glass optical fibers also has disadvantages as compared to plastic optical fibers. Glass optical fibers are more fragile than plastic optical fibers. Glass optical fibers may be also more likely to break during installation of these types of fibers.

Glass optical fibers are more expensive than plastic optical fibers. Further, components used in networks with glass optical fibers may be more expensive than components used in networks with plastic optical fibers. As a result, the use of glass optical fibers in networks may increase costs of installing and/or replacing glass optical fibers. Accordingly, it would be advantageous to have a method and apparatus,

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which takes into account one or more of the issues discussed above as well as possibly other issues.

SUMMARY

In one advantageous embodiment an apparatus comprises a substrate having a type of conductivity, an intrinsic region above the substrate, and a metal layer on a portion of the surface of the intrinsic region. The intrinsic region has a surface. The metal layer may have a thickness that is configured to allow a plurality of photons to pass through the metal layer into the intrinsic region and form a rectifying contact with the intrinsic region.

In another advantageous embodiment, an apparatus comprises a substrate having an n-type conductivity, an intrinsic region above the substrate, a metal layer on a portion of the surface of the intrinsic region, and an area having a p-type conductivity in which the area extends from the surface into the intrinsic region. The intrinsic region has a surface. The metal layer may have a thickness from about 50 angstroms to about 100 angstroms. The thickness may be configured to allow a plurality of photons to pass through the metal layer into the intrinsic region and form a rectifying contact with the intrinsic region. The area may surround the portion of the surface of the intrinsic region around the metal layer and may be configured to reduce a current moving across the surface outside of the intrinsic region surrounded by the area.

In yet another advantageous embodiment, a method for forming an optical detector is present. A substrate having a type of conductivity may be formed. An intrinsic region may be formed above the substrate. The intrinsic region has a surface. A metal layer may be formed on a portion of the surface of the intrinsic region. The metal layer may have a thickness configured to allow a plurality of photons to pass through the metal layer into the intrinsic region and form a rectifying contact with the intrinsic region.

The features, functions, and advantages can be achieved independently in various embodiments of the present disclosure or may be combined in yet other embodiments in which further details can be seen with reference to the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the advantageous embodiments are set forth in the appended claims. The advantageous embodiments, however, as well as a preferred mode of use, further objectives and advantages thereof, will best be understood by reference to the following detailed description of an advantageous embodiment of the present disclosure when read in conjunction with the accompanying drawings, wherein:

FIG. 1 is an illustration of an aircraft manufacturing and service method in accordance with an advantageous embodiment;

FIG. 2 is an illustration of an aircraft in which an advantageous embodiment may be implemented;

FIG. 3 is an illustration of an optical signal environment in accordance with an advantageous embodiment;

FIG. 4 is an illustration of an optical detector in which an advantageous embodiment may be implemented;

FIG. 5 is an illustration of a transceiver in which an advantageous embodiment may be implemented;

FIG. 6 is an illustration of an optical receiver in which an advantageous embodiment may be implemented;

FIG. 7 is an illustration of an optical transmitter in which an advantageous embodiment may be implemented;

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FIG. 8 is an illustration of a transceiver in which an advantageous embodiment may be implemented;

FIG. 9 is an illustration of a top view of a transceiver in accordance with an advantageous embodiment;

FIG. 10 is an illustration of a bottom view of a transceiver in accordance with an advantageous embodiment;

FIG. 11 is an illustration of a transceiver in accordance with an advantageous embodiment;

FIG. 12 is an illustration of a transceiver in which an advantageous embodiment may be implemented;

FIG. 13 is an illustration of a top view of a transceiver in accordance with an advantageous embodiment;

FIG. 14 is an illustration of a bottom view of a transceiver in accordance with an advantageous embodiment;

FIG. 15 is an illustration of a cross-sectional view of a portion of an integrated circuit during fabrication in which an advantageous embodiment may be implemented;

FIG. 16 is an illustration of a cross-sectional view of a portion of an integrated circuit during fabrication in which an advantageous embodiment may be implemented;

FIG. 17 is an illustration of a cross-sectional view of a portion of an integrated circuit during fabrication in which an advantageous embodiment may be implemented;

FIG. 18 is an illustration of a cross-sectional view of a portion of an integrated circuit during fabrication in which an advantageous embodiment may be implemented;

FIG. 19 is an illustration of a cross-sectional view of a portion of an integrated circuit during fabrication in which an advantageous embodiment may be implemented;

FIG. 20 is an illustration of a cross-sectional view of a portion of an integrated circuit during fabrication in which an advantageous embodiment may be implemented;

FIG. 21 is an illustration of a cross-sectional view of a portion of an integrated circuit during fabrication in which an advantageous embodiment may be implemented;

FIG. 22 is an illustration of a flowchart of a process for processing optical signals in accordance with an advantageous embodiment;

FIG. 23 is an illustration of a flowchart of a process for processing optical signals in accordance with an advantageous embodiment;

FIG. 24 is an illustration of a flowchart of a process for forming an optical detector in accordance with an advantageous embodiment;

FIG. 25 is an illustration of a flowchart of a process for forming an optical detector in accordance with an advantageous embodiment; and

FIG. 26 is an illustration of a flowchart of a process for forming an optical detector in accordance with an advantageous embodiment.

DETAILED DESCRIPTION

Referring more particularly to the drawings, embodiments of the disclosure may be described in the context of aircraft manufacturing and service method **100** as shown in FIG. **1** and aircraft **200** as shown in FIG. **2**. Turning first to FIG. **1**, an illustration of an aircraft manufacturing and service method is depicted in accordance with an advantageous embodiment. During pre-production, aircraft manufacturing and service method **100** may include specification and design **102** of aircraft **200** in FIG. **2** and material procurement **104**.

During production, component and subassembly manufacturing **106** and system integration **108** of aircraft **200** in FIG. **2** takes place. Thereafter, aircraft **200** in FIG. **2** may go through certification and delivery **110** in order to be placed in service **112**. While in service by a customer, aircraft **200** in

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FIG. **2** is scheduled for routine maintenance and service **114**, which may include modification, reconfiguration, refurbishment, and other maintenance or service.

Each of the processes of aircraft manufacturing and service method **100** may be performed or carried out by a system integrator, a third party, and/or an operator. In these examples, the operator may be a customer. For the purposes of this description, a system integrator may include, without limitation, any number of aircraft manufacturers and major-system subcontractors; a third party may include, without limitation, any number of vendors, subcontractors, and suppliers; and an operator may be an airline, leasing company, military entity, service organization, and so on.

With reference now to FIG. **2**, an illustration of an aircraft is depicted in which an advantageous embodiment may be implemented. In this example, aircraft **200** is produced by aircraft manufacturing and service method **100** in FIG. **1** and may include airframe **202** with plurality of systems **204** and interior **206**. Examples of systems **204** include one or more of propulsion system **208**, electrical system **210**, hydraulic system **212**, and environmental system **214**, and optical network **216**. Any number of other systems may be included. Although an aerospace example is shown, different advantageous embodiments may be applied to other industries, such as the automotive industry.

Apparatus and methods embodied herein may be employed during at least one of the stages of aircraft manufacturing and service method **100** in FIG. **1**. As used herein, the phrase “at least one of”, when used with a list of items, means that different combinations of one or more of the listed items may be used and only one of each item in the list may be needed. For example, “at least one of item A, item B, and item C” may include, for example, without limitation, item A or item A and item B. This example also may include item A, item B, and item C or item B and item C.

In one illustrative example, components or subassemblies produced in component and subassembly manufacturing **106** in FIG. **1** may be fabricated or manufactured in a manner similar to components or subassemblies produced while aircraft **200** is in service **112** in FIG. **1**. As yet another example, a number of apparatus embodiments, method embodiments, or a combination thereof may be utilized during production stages, such as component and subassembly manufacturing **106** and system integration **108** in FIG. **1**.

A number, when referring to items means, one or more items. For example, a number of apparatus embodiments is one or more apparatus embodiments. A number of apparatus embodiments, method embodiments, or a combination thereof may be utilized while aircraft **200** is in service **112** and/or during maintenance and service **114** in FIG. **1**. The use of a number of the different advantageous embodiments may substantially expedite the assembly of and/or reduce the cost of aircraft **200**.

A first component may be considered to be associated with a second component by being secured to the second component, bonded to the second component, fastened to the second component, and/or connected to the second component in some other suitable manner. The first component also may be connected to the second component through using a third component. The first component may also be considered to be associated with the second component by being formed as part of and/or an extension of the second component.

The different advantageous embodiments recognize and take into account a number of different considerations. For example, the different advantageous embodiments recognize and take into account that many currently available long-distance networks use glass optical fibers to transmit infor-

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mation. However, the different advantageous embodiments recognize that plastic optical fibers have a greater durability as compared to glass fibers. One solution may involve replacing glass optical fibers with plastic optical fibers. However, with plastic optical fibers, signal loss increases as the distance over which the signal travels increases. The different advantageous embodiments recognize that as a result of this signal loss, errors may occur while transmitting information through plastic optical fibers.

Further, the different advantageous embodiments also recognize and take into account that components used in networks configured for the use of glass optical fibers may not have a desired level of sensitivity for use with plastic optical fibers. More specifically, the use of plastic optical fibers in networks may require that the components in the networks have a greater level of sensitivity as compared to the use of glass optical fibers. One solution may involve using components that are currently configured for use with plastic optical fibers. However, the different advantageous embodiments recognize and take into account that these components may not provide the desired level of sensitivity for transmitting information over distances of about 30 meters or greater without error.

Thus, the different advantageous embodiments provide a method and apparatus for a transceiver for networks with plastic optical fibers. In one advantageous embodiment, an apparatus comprises an optical transmitter; an optical detector configured to receive optical signals from an optical fiber; an optical splitter having a first port, a second port coupled to the optical detector by the optical fiber, and a third port coupled to the optical transmitter; and a two stage amplifier system connected to an output of the optical detector. An input surface of the optical detector has a diameter that is substantially equal to a diameter of a core in the optical fiber. The diameter of the input surface of the optical detector reduces capacitance and reduces signal distortion. The optical splitter is configured to receive a first optical signal at the first port. The optical splitter is configured to send the first optical signal to the second port and send a second optical signal received at the third port to the first port.

With reference now to FIG. 3, an illustration of an optical signal environment is depicted in accordance with an advantageous embodiment. In this illustrative example, optical signal environment 300 may be implemented in a network such as, for example, optical network 216 in FIG. 2. Further, optical signal environment 300 may be implemented in platform 302. In this depicted example, platform 302 takes the form of aircraft 200 in FIG. 2. Optical signal environment 300 may be comprised of a number of components used to transmit information. In this illustrative example, optical signal environment 300 includes transceiver 304. Transceiver 304 includes optical receiver 306 and optical transmitter 308. As depicted, optical receiver 306 is coupled to optical transmitter 308.

As used herein, a first component may be considered to be coupled to a second component by being secured to the second component, bonded to the second component, fastened to the second component, and/or connected to the second component in some other suitable manner. The first component also may be coupled to the second component through using a third component. The first component may also be considered to be coupled to the second component by being formed as part of and/or an extension of the second component. Also as used herein, optical components may be coupled to other components. When optical components are coupled to other components there may be a small gap between the components.

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In these illustrative examples, optical receiver 306 includes optical detector 310 and two stage amplifier system 311. Optical detector 310 may take the form of, Schottky barrier diode 313, PIN diode 315, or some other suitable type of optical detector. For example, PIN diode 315 may be a diode having a p-type layer on an intrinsic layer on an n-type layer.

Optical detector 310 is configured to receive optical signals 316 traveling through optical fibers 318 in this example. In these illustrative examples, optical signals 316 may be directly received or indirectly received by optical detector 310. As used herein, "directly received" means without being sent or received by an additional component, and "indirectly received" means being sent or received by at least one additional component.

In these illustrative examples, optical fibers 318 take the form of plastic optical fibers 319. In other advantageous embodiments, optical fibers 318 may take the form of glass optical fibers and/or some other suitable type of optical fiber. Optical fibers 318 include first optical fiber 320 and second optical fiber 322 in this example.

Optical detector 310 may receive first optical signal 324 traveling through first optical fiber 320 at input surface 326 of optical detector 310. In this illustrative example, input surface 326 has diameter 328. Diameter 328 is selected such that diameter 328 is substantially the same as diameter 330 of core 332 in first optical fiber 320. Core 332 is the portion of first optical fiber 320 through which first optical signal 324 travels.

First optical signal 324 is received at input surface 326 of optical detector 310 as photons traveling through core 332 of first optical fiber 320. These photons enter input surface 326 of optical detector 310 and generate photoelectrons in optical detector 310. These photoelectrons in turn produce current signal 333 at output 334 of optical detector 310.

By having diameter 328 of input surface 326 and diameter 330 of core 332 be substantially the same, signal loss for first optical signal 324 at optical detector 310 may be reduced. For example, an optical detector with an input surface that is smaller than core 332 of first optical fiber 320 may not receive all of the photons traveling in first optical signal 324. This smaller input surface also may lead to distortion of current signal 333 generated by the optical detector. On the other hand, using an optical detector with an input surface having a diameter that is larger than the diameter of core 332 of first optical fiber 320 increases capacitance of the optical detector. The increased capacitance may cause a time delay and distortion of the signal generated by an optical detector reducing sensitivity of the optical detector and the optical receiver.

By having diameter 328 of input surface 326 and diameter 330 of core 332 be substantially the same, signal distortion of current signal 333 and capacitance of optical detector 310 may be reduced. As a result, a level of sensitivity of optical receiver 306 may be increased.

As depicted in this example, current signal 333 is output through output 334 and received by two stage amplifier system 311 in optical receiver 306. In these illustrative examples, two stage amplifier system 311 amplifies current signal 333 received to increase a level of sensitivity of transceiver 304. Two stage amplifier system 311 may include first amplifier 336, second amplifier 338, and/or other suitable components. First amplifier 336 has input 340 of first amplifier 336 connected to output 334 of optical detector 310. Current signal 333 is received at input 340 of first amplifier 336. Output 342 of first amplifier 336 is connected to input 344 of second amplifier 338. As used herein, a first component may be connected to a second component through using a third component. The first component may also be considered to be

connected to the second component by being formed as part of, and/or an extension of, the second component. Further, components may be electrically connected using bonding, soldering, wiring and/or any other suitable electrical connection.

In this illustrative example, first amplifier 336 takes the form of current-to-voltage converter 346. Current-to-voltage converter 346 may also be referred to as a transimpedance amplifier. Current-to-voltage converter 346 has a gain equal to a feedback resistance. Output 342 of current-to-voltage converter 346 is connected to input 344 of second amplifier 338.

In this depicted example, second amplifier 338 takes the form of limiting amplifier 348. Limiting amplifier 348 reduces and/or limits variations in power in the voltage signal received at input 344 from output 342. Limiting amplifier 348 provides a substantially constant output signal at output 349 of limiting amplifier 348 over a range of input voltage signals. In these examples, current-to-voltage converter 346 and limiting amplifier 348 are selected to match the gain and noise requirements of optical detector 310.

In these illustrative examples, optical transmitter 308 includes light emitting diode 350 and driver amplifier 352. Driver amplifier 352 sends current 354 to bias light emitting diode 350. Light emitting diode 350 emits light waves that form second optical signal 356. Second optical signal 356 may be transmitted from optical transmitter 308 and travel through second optical fiber 322 in optical fibers 318. In this depicted example, light emitting diode 350 may be a green light emitting diode, a red light emitting diode, a blue light emitting diode, or some other type of light source suitable for transmitting optical signals.

As depicted in these illustrative examples, transceiver 304 may also include optical splitter 358. Optical splitter 358 has first port 360, second port 362, and third port 364. In these illustrative examples, optical splitter 358 is bi-directional. In other words, optical splitter 358 may both receive and send optical signals. For example, first port 360 of optical splitter 358 is bi-directional. In other words, optical signals may be sent from, and received by, first port 360 of optical splitter 358.

In this illustrative example, first port 360 receives first optical signal 324 traveling through first optical fiber 320. First port 360 also sends first optical signal 324 to second port 362. Second port 362 sends first optical signal 324 traveling through first optical fiber 320 to input surface 326 of optical detector 310. Third port 364 receives second optical signal 356 from optical transmitter 308 and sends second optical signal 356 to first port 360.

In this depicted example, optical splitter 358 includes filter 361. Filter 361 may receive first optical signal 324 traveling through first optical fiber 320. Filter 361 allows first range of wavelengths 363 of first optical signal 324 to pass to first port 360 and/or second port 362 of optical splitter 358. Further, filter 361 may receive second optical signal 356 from third port 364. Filter 361 reflects second range of wavelengths 365 of second optical signal 356 to first port 360 and/or second port 362. In other advantageous embodiments, filter 361 may reflect first range of wavelengths 363 of first optical signal 324 and allow second range of wavelengths 365 to pass.

As depicted in these examples, transceiver 304 also includes printed wiring board 366. Printed wiring board 366 may be comprised of number of electrically conductive lines 368, substantially planar insulating structure 370, and/or other suitable components. Substantially planar insulating structure 370 is a structure made of a material that is substan-

tially non-conductive with respect to electrical signals or current. Substantially planar insulating structure 370 has number of surfaces 375.

Number of surfaces 375 includes first surface 374 and second surface 376. First surface 374 and second surface 376 may be substantially opposite to each other in this depicted example. In these illustrative examples, optical detector 310 may be located on first surface 374 of substantially planar insulating structure 370. Optical detector 310 may be connected directly to substantially planar insulating structure 370 in this example. Further, optical transmitter 308 may be located on second surface 376 of substantially planar insulating structure 370. Optical transmitter 308 may also be connected directly to substantially planar insulating structure 370. As used herein, "directly connected to" means being attached, secured, bonded and/or connected to without an additional component, and "indirectly connected to" means being attached, secured, bonded, and/or connected to by at least one additional component.

In some advantageous embodiments, optical detector 310 may be located in first housing 378. First housing 378 may be connected to first surface 374 of substantially planar insulating structure 370 directly or indirectly by first structure 381. Further, in these advantageous embodiments, optical transmitter 308 may be located in second housing 380. Second housing 380 may be connected to second surface 376 of substantially planar insulating structure 370 directly or indirectly through second structure 382. Second structure 382 may take the form of heat sink 383 in these examples. First housing 378 and second housing 380 may be hermetically sealed containers. For example, without limitation, first housing 378 and second housing 380 may be hermetically sealed TO-18 or TO-46 can with a glass window or semi-spherical lensed cap. These components may be commercially available from Independent Business and Scientific Group Company Limited.

In these advantageous embodiments, first housing 378 may also house first amplifier 336 of two stage amplifier system 311. Second amplifier 338 of two stage amplifier system 311 may be located outside of first housing 378 on surface 384 of substantially planar insulating structure 370. In these examples, surface 384 may be first surface 374. In other examples, surface 384 may be second surface 376 or some other suitable surface in number of surfaces 375. In yet other advantageous embodiments, both first amplifier 336 and second amplifier 338 may be located outside of first housing 378 on surface 384 of substantially planar insulating structure 370. In still other advantageous embodiments, first amplifier 336 and second amplifier 338 may be located on different surfaces in number of surfaces 375.

The illustration of optical signal environment 300 in FIG. 3 is not meant to imply physical or architectural limitations to the manner in which different advantageous embodiments may be implemented. Other components, in addition to and/or in place of the ones illustrated, may be used. Some components may be unnecessary in some advantageous embodiments. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined and/or divided into different blocks when implemented in different advantageous embodiments.

For example, in other advantageous embodiments, transceiver 304 may include additional optical receivers and/or optical transmitters in addition to optical receiver 306 and/or optical transmitter 308. Further, in some advantageous embodiments, optical signal environment 300 may include additional transceivers in addition to transceiver 304 or any

additional number of optical receivers, optical transmitters, optical splitters, and/or other suitable components.

In still other advantageous embodiments, optical signal environment 300 may have optical signals 316 traveling on optical fibers 318 in addition to first optical fiber 320 and second optical fiber 322. In some examples, optical splitter 358 may not include filter 361. In yet other advantageous embodiments, first port 360 and/or third port 364 may be configured to receive optical signals 316 traveling through mediums other than optical fibers 318.

In other advantageous embodiments, platform 302 may take other forms. In the illustrative examples, platform 302 may be a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, a space-based structure, an aircraft, a submarine, a bus, a personnel carrier, a tank, a train, an automobile, a spacecraft, a space station, a satellite, a bridge, a dam, a surface ship, and/or some other suitable platform. Optical signal environment 300 may be implemented in any number of these platforms.

With reference now to FIG. 4, an illustration of an optical detector is depicted in which an advantageous embodiment may be implemented. In this illustrative example, optical detector 400 is an example of one implementation of optical detector 310 in FIG. 3.

Optical detector 400 takes the form of Schottky barrier diode 402 in this example. Schottky barrier diode 402 is a metal semiconductor device formed by layers of semiconductor materials and metal materials. These layers include substrate 404, intrinsic region 406, first metal layer 408, second metal layer 410, and third metal layer 412.

In this illustrative example, substrate 404 is a layer of semiconductor material upon which Schottky barrier diode 402 is formed. In other words, substrate 404 is a base layer of Schottky barrier diode 402 upon which other layers may be added. The semiconductor material selected for substrate 404 may be, for example, without limitation, silicon, germanium, gallium arsenide, indium gallium arsenide, indium phosphide, and/or any other suitable semiconductor material.

As depicted, substrate 404 has first type of conductivity 414. First type of conductivity 414 may be determined by the introduction of dopants into substrate 404. In this manner, substrate 404 is doped. In these examples, a dopant is any chemical element that does not have the same atomic structure as the semiconductor material to which the dopant is added. Dopants may include, for example, without limitation, phosphorus, boron, and/or other suitable substances.

The introduction of dopants into substrate 404 adds electrons or adds holes to substrate 404. These electrons and/or holes may increase the conductivity of substrate 404. When electrons are added by dopants to substrate 404, first type of conductivity 414 may be n-type 415. When holes are added by dopants to substrate 404, first type of conductivity 414 may be p-type 417. In other words, when electrons are added to substrate 404, Schottky barrier diode 402 is an n-type semiconductor device. When holes are added to substrate 404, Schottky barrier diode 402 is a p-type semiconductor device. In this manner, substrate 404 takes the form of an extrinsic semiconductor. An extrinsic semiconductor has a substantially unequal number of electrons and holes.

In these illustrative examples, intrinsic region 406 is a layer of semiconductor material that lies on top of substrate 404. Intrinsic region 406 has surface 416. In these examples, intrinsic region 406 has substantially few to no dopants within intrinsic region 406. In other words, intrinsic region 406 has a substantially equal number of electrons as compared to the number of holes. As a specific example, intrinsic region 406 consists of silicon 418 with substantially no dopants. Intrinsic

region 406 may also be comprised of silicon 418. For example, silicon 418 in intrinsic region 406 may have dopant concentration 420 substantially equal to or less than about 1×10^{15} dopant atoms per cubic centimeter.

Intrinsic region 406 is formed on substrate 404. Intrinsic region 406 may be formed on substrate 404 in a number of different ways. For example, intrinsic region 406 may be grown, deposited, or formed on substrate 404 using any suitable process. Further, intrinsic region 406 has thickness 422. In one illustrative example, thickness 422 of intrinsic region 406 is substantially equal to or greater than about 1 micron.

First metal layer 408 is formed on portion 424 of surface 416 of intrinsic region 406. First metal layer 408 may be formed in a number of different ways. For example, first metal layer 408 may be deposited onto intrinsic region 406 using evaporation techniques, photolithographic masks, and/or other suitable techniques.

The junction of first metal layer 408 with intrinsic region 406 forms depletion region 430 extending from surface 416 into intrinsic region 406. Depletion region 430 is a region in which substantially all free electrons have been removed.

First metal layer 408 has thickness 432. Thickness 432 is selected to allow plurality of photons 434 to pass through first metal layer 408. In one illustrative example, thickness 432 of first metal layer 408 may be selected with a value from about 50 angstroms to about 100 angstroms.

In this manner, thickness 432 of first metal layer 408 allows plurality of photons 434 to enter intrinsic region 406. Optical detector 400 is a metal on semiconductor detector. Depletion region 430 in optical detector 400 extends from surface 416 of intrinsic region 406 into intrinsic region 406. Plurality of photons 434 pass through first metal layer 408 and enter directly into depletion region 430 in intrinsic region 406. In this manner, a greater percentage of photons enter depletion region 430 in intrinsic region 406 as compared to a detector without first metal layer 408, such as a semiconductor on semiconductor detector, for example a PIN diode. Further, plurality of photons 434 that enter depletion region 430 generate photoelectrons which move in intrinsic region 406 towards substrate 404.

First metal layer 408 forms rectifying contact 436 with intrinsic region 406. A rectifying contact is a contact that results in a larger current flow in the forward bias direction of the diode than a current flow in the reverse bias direction. This type of current flow is the physical phenomena of a potential barrier and also is called a Schottky barrier. This type of current flow is formed at the interface of first metal layer 408 and intrinsic region 406.

In these illustrative examples, first metal layer 408 may be comprised of gold 426, indium-tin-oxide 428, and/or other suitable metals. The chemical properties of metals such as gold 426 and indium-tin-oxide 428, allow first metal layer 408 to be deposited having thickness 432.

In these illustrative examples, first metal layer 408 has layer 431 of material 433 on surface 435 of first metal layer 408. Layer 431 is capable of receiving an optical signal traveling through an optical fiber. Layer 431 may be an example of one implementation of input surface 326 of optical detector 310 in FIG. 3. In particular, plurality of photons 434 may hit layer 431. Material 433 of layer 431 is selected to reduce the reflection of plurality of photons 434 that are received at layer 431. For example, layer 431 of material 433 may be antireflective coating 446. In these illustrative examples antireflective coating 446 may be comprised of a material selected from one of silicon nitride, silicon dioxide, and any other suitable antireflective material.

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In one advantageous embodiment, raised portion **440** is formed on portion **424** of surface **416** in contact with first metal layer **408**. Raised portion **440** can be formed by etching surface **416** of intrinsic region **406**. Etching surface **416** to form raised portion **440** decreases the current **444**. Current **444** is a source of shot noise, of the Schottky barrier diode **402**.

In this illustrative example, optical detector **400** includes area **438**. Area **438** extends from surface **416** into intrinsic region **406**. Area **438** surrounds all of, or part of, portion **424** of surface **416** in contact with first metal layer **408** in this example. Area **438** reduces dark current **444** that flows across surface **416** of intrinsic region **406**. For example, current **444** may be a dark current which is the source of shot noise in optical detector **400**.

Area **438** reduces a flow of electrons across surface **416** of intrinsic region **406**. As plurality of photons **434** enter intrinsic region **406**, area **438** allows a greater percentage of electrons to move toward substrate **404** as compared to when area **438** is not present. This increase in the number of electrons moved is due to the reduced flow of electrons across surface **416** of intrinsic region **406**.

In this illustrative example, area **438** has second type of conductivity **442**. Second type of conductivity **442** is an opposite type of conductivity as compared to first type of conductivity **414** for substrate **404**. In these illustrative examples, second type of conductivity **442** is p-type **444**. In other illustrative examples, second type of conductivity **442** may be n-type **445**.

Second type of conductivity **442** of area **438** may be formed in intrinsic region **406** in a number of different ways. For example, second type of conductivity **442** may be formed by introducing dopants into intrinsic region **406**. In some advantageous embodiments, zinc may be diffused into intrinsic region **406**. In other advantageous embodiments, ion implantation may be used.

In these illustrative examples, Schottky barrier diode **402** also includes second metal layer **410**. Second metal layer **410** may be formed to be in contact with surface **450** of substrate **404** to form an ohmic contact. Second metal layer **410** may be formed in a number of different ways. For example, second metal layer **410** may be deposited onto surface **450** of substrate **404** using evaporation techniques, photolithographic masks, and/or other suitable types of techniques. In this illustrative example, surface **450** is substantially opposite to surface **416** of intrinsic region **406**.

Additionally, third metal layer **412** may be formed to be in contact with portion **454** of surface **435** of first metal layer **408**. Third metal layer **412** may also be deposited onto portion **454** of surface **435** of first metal layer **408** using evaporation techniques, sputtering, photolithographic masks, and/or other suitable types of techniques.

The illustration of optical detector **400** in FIG. **4** is not meant to imply physical or architectural limitations to the manner in which different advantageous embodiments may be implemented. Other components in addition to, and/or in place of, the ones illustrated may be used. Some components may be unnecessary in some advantageous embodiments. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined and/or divided into different blocks when implemented in different advantageous embodiments.

For example, in some advantageous embodiments, intrinsic region **406** may be comprised of a semiconductor material other than silicon. The semiconductor material may be, for example, without limitation, germanium. In other advantageous embodiments, first metal layer **408** may be comprised

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of metals in addition to, or in place of, gold **426** and/or indium-tin-oxide **428**, such as, for example, without limitation, silver, platinum, copper, and/or nickel.

With reference now to FIG. **5**, an illustration of a transceiver is depicted in which an advantageous embodiment may be implemented. In these illustrative examples, transceiver **500** is an example of one implementation for transceiver **304** in FIG. **3**. As depicted, transceiver **500** includes optical splitter **502**, light emitting diode **504**, optical detector **506**, transimpedance amplifier **508**, limiting amplifier **509**, and driving amplifier **511**.

In this illustrative example, optical splitter **502** is an example of one implementation of optical splitter **358** in FIG. **3**. As depicted, optical splitter **502** is a plastic optical fiber splitter with first port **510**, second port **512**, and third port **514**. Optical splitter **502** sends and/or receives optical signals traveling through plastic optical fibers in this illustrative example.

For example, optical splitter **502** may receive signal **516** at third port **514** and may send signal **516** through first port **510**. Signal **516** is sent to third port **514** by light emitting diode **504**. In these examples, light emitting diode **504** may be red, blue, or green light emitting diode. Optical splitter receives signal **518** at first port **510** and may send signal **518** to optical detector **506** through second port **512**. In other advantageous embodiments, optical signals are sent and/or received using a medium other than plastic optical fibers, such as glass optical fibers.

In this depicted example, optical detector **506** may be an example of one implementation of optical detector **310** in FIG. **3** and/or optical detector **400** in FIG. **4**. Optical detector **506** may take the form of, for example, a Schottky barrier diode, a PIN diode, or some other suitable type of optical detector.

As depicted, optical detector **506** is connected to transimpedance amplifier **508**. In these illustrative examples, transimpedance amplifier **508** may be implemented using MAX3657 transimpedance amplifier provided by Maxim® Integrated Products, Inc. Further, transimpedance amplifier **508** is connected to limiting amplifier **509**. In this depicted example, limiting amplifier **509** may be implemented using MAX3969 limiting amplifier provided by Maxim® Integrated Products, Inc.

Further, light emitting diode **504** is connected to driver amplifier **511**. In these illustrative examples, driver amplifier **511** may be implemented using Maxim® MAX3967 A amplifier provided by Maxim® Integrated Products, Inc.

With reference now to FIG. **6**, an illustration of an optical receiver is depicted in which an advantageous embodiment may be implemented. In these illustrative examples, optical receiver **600** is an example of one implementation of optical receiver **306** in FIG. **3**. As depicted, optical detector **602** is connected to two stage amplifier system **604**. Optical detector **602** is an example of one implementation of optical detector **310** in FIG. **3** and/or optical detector **400** in FIG. **4**. Two stage amplifier is an example of one implementation of two stage amplifier system **311** in FIG. **3**.

Optical detector **602** receives optical signal **606**. In a network with plastic optical fibers, optical signal **606** will have a wavelength in the visible spectrum. For example, optical signal **606** may have a wavelength of about 650 nanometers. This wavelength corresponds to a red wavelength in the visible spectrum. In some illustrative examples, optical signal **606** may have a wavelength of about 500 nanometers, which is a green wavelength. In other illustrative examples, optical signal **606** may have a wavelength of about 450 nanometers, which is a blue wavelength.

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For a signal with a wavelength of about 650 nanometers, optical detector **602** may be implemented using a S5971 silicon PIN detector provided by Hamamatsu® Corporation. Alternatively, for a signal with a wavelength of about 500 nanometers, optical detector **602** may be implemented using a S5973 silicon PIN detector provided by Hamamatsu® Corporation.

In this illustrative example, two stage amplifier system **604** includes transimpedance amplifier **608** connected to limiting amplifier **610**. Alternating current coupling capacitors **612** are used to connect transimpedance amplifier **608** to limiting amplifier **610**. Alternating current coupling capacitors **612** may be selected to have a capacitance of about 0.01 microfarads.

As depicted, variable resistor **614** is connected to transimpedance amplifier **608**. Variable resistor **614** allows two stage amplifier system **604** to be tuned for a desired Signal Detect (SD) sensitivity. For plastic optical fiber networks, the desired signal detect sensitivity level of optical receiver **600** may be a sensitivity having a value substantially equal to or less than about -32 decibel milliwatts.

With reference now to FIG. 7, an illustration of an optical transmitter is depicted in which an advantageous embodiment may be implemented. In this illustrative example, optical transmitter **700** is an example of one implementation of optical transmitter **314** in FIG. 3. As depicted, optical transmitter **700** includes driver amplifier **702** and light emitting diode **704**.

In this illustrative example, driver amplifier **702** sends a bias current and a modulation current to drive light emitting diode **704**. The amount of bias current and modulation current sent is selected to allow light emitting diode **704** to generate at least about one milliwatt of average optical power. The optical power generated is coupled into an optical fiber, such as second optical fiber **322** in FIG. 3. Since light signal from the light emitting diodes are light pulses, the average power is the power of these output light pulses averaged over time.

In these depicted examples, when light emitting diode **704** is a red light emitting diode, light is emitted with a wavelength of about 650 nanometers. Alternatively, when light emitting diode **704** is a green light emitting diode, light is emitted with a wavelength of about 500 nanometers. Further, when light emitting diode **704** is a blue light emitting diode, light is emitted with wavelength of about 450 nanometers. In these examples, light emitting diode **704** may be a L10762 or L8628 light emitting diode from Hamamatsu® Corporation or a 216003 light emitting diode from Zarlink® Semiconductor, Incorporated.

With reference now to FIG. 8, an illustration of a transceiver is depicted in which an advantageous embodiment may be implemented. In this illustrative example, transceiver **800** is an example of one implementation of transceiver **304** in optical signal environment **300** in FIG. 3. As depicted, transceiver **800** is seen from a side view. Transceiver **800** includes printed wiring board **801**, optical detector **802**, light emitting diode **804**, transimpedance amplifier **806**, limiting amplifier **808**, driver amplifier **810**, and plastic optical fiber splitter **812**.

In this illustrative example, printed wiring board **801** is an example of one implementation of substantially planar insulating structure **370** in FIG. 3. Printed wiring board **801** has first surface **814** and second surface **816**. As depicted, optical detector **802** is located in housing **818**. Housing **818** is located on first surface **814** of printed wiring board **801**. Further, housing **818** may be connected to first surface **814** using, for example, a thermally conductive epoxy. In this manner, optical detector **802** is connected to first surface **814** of printed wiring board **801**. Housing **818** may take the form of a her-

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metically sealed TO 18 can with a glass window cap or a lensed cap in this illustrative example.

As depicted, transimpedance amplifier **806** and limiting amplifier **808** are also connected to first surface **814** of printed wiring board **801**. In these examples, transimpedance amplifier **806** and limiting amplifier **808** are located outside of housing **818**. Transimpedance amplifier **806**, limiting amplifier **808**, and optical detector **802** comprise optical receiver **819**.

Light emitting diode **804** is connected to driver amplifier **810** to form transmitter **825**. As depicted, both light emitting diode **804** and driver amplifier **810** are located on second surface **816** of printed wiring board **801**. Light emitting diode **804** is located in housing **820**. Housing **820** and driver amplifier **810** are connected to second surface **816** of printed wiring board **801**. Housing **820** may be connected to second surface **816** using a thermally conductive epoxy. Housing **820** may take the form of a hermetically sealed TO 18 can with a glass window cap or a lensed cap in this illustrative example.

Further, in this depicted example, housing **820** is connected to printed wiring board **801** using structure **821**. Structure **821** may take the form of a metal holder in this illustrative example. The connection of housing **820** to printed wiring board **801** through structure **821** forms a heat sink. This heat sink allows heat generated by light emitting diode **804** in housing **820** to be reduced. In other words, this heat sink conducts the heat generated by light emitting diode **804** away from light emitting diode **804** and towards printed wiring board **801**. This conduction of heat away from light emitting diode **804** prevents light emitting diode **804** from overheating.

In this illustrative example, plastic optical fiber splitter **812** has first arm **826** and second arm **828**. First arm **826** is connected to housing **818** on first surface **814**. Second arm **828** is connected to housing **820** on second surface **816**. This configuration of first arm **826** and second arm **828** saves surface space on printed wiring board **801**. In these examples, these savings in surface space may be about 50 percent as compared to transceivers having receivers and transmitters on the same surface of the printed wiring board. This configuration also reduces the bending of first arm **826** and second arm **828** of plastic optical fiber splitter **812**. Further, this configuration improves the reliability and optical coupling efficiency of plastic optical fiber splitter **812**. For example, the configuration may reduce the bending of the arms of plastic optical fiber splitter **812**.

For example, transceiver **800** may be formed with dimensions that allow savings in surface space. These dimensions for transceiver **800** may be, for example, without limitation, about 0.3 inches in width, about 1.9 inches in length, and about 0.5 inches in height.

First arm **826** of plastic optical fiber splitter **812** couples an input of transceiver **800** to optical detector **802**. This input may be an output of plastic optical fiber **830**. For example, plastic optical fiber splitter **812** may receive an optical signal traveling through plastic optical fiber **830**.

Second arm **828** of plastic optical fiber splitter **812** couples transmitter **825** to an output of transceiver **800**. Further, second arm **828** couples signal power generated by light emitting diode **804** to an output of transceiver **800**. In these illustrative examples, both first arm **826** and second arm **828** have a diameter of about one millimeter. This diameter is substantially the same as the diameter of an input surface of optical detector **802**.

With reference now to FIG. 9, an illustration of a top view of a transceiver is depicted in accordance with an advanta-

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geous embodiment. In this illustrative example, transceiver **800** is seen from first surface **814**.

With reference now to FIG. **10**, an illustration of a bottom view of a transceiver is depicted in accordance with an advantageous embodiment. In this illustrative example, transceiver **800** is seen from second surface **816**.

With reference now to FIG. **11**, an illustration of a transceiver is depicted in accordance with an advantageous embodiment. In this illustrative example, transceiver **800** has both optical detector **802** and transimpedance amplifier **806** located within housing **818**.

This configuration reduces a distance of the connection of optical detector **802** to transimpedance amplifier **806**. This reduced distance, in turn, increases a sensitivity of optical receiver **819**. Further, the reduced distance of the connection between optical detector **802** and transimpedance amplifier **806** reduces interference that may occur through the distance of the connection.

Still further, having both optical detector **802** and transimpedance amplifier **806** located in housing **818** allows surface space savings for transceiver **800**. For example, the configuration of transceiver **800** in FIG. **11** may have dimensions that are smaller than the configuration of transceiver **800** in FIGS. **8**, **9**, and **10**. In FIG. **11**, transceiver **800** may have dimensions of about 0.3 inches in width, about 1.7 inches in length, and about 0.5 inches in height.

With reference now to FIG. **12**, an illustration of a transceiver is depicted in which an advantageous embodiment may be implemented. In this illustrative example, transceiver **1200** is an example of one implementation of transceiver **304** in optical signal environment **300** in FIG. **3**. As depicted, transceiver **1200** is seen from a side view. Transceiver **1200** includes printed wiring board **1201**, optical detector **1202**, light emitting diode **1204**, transimpedance amplifier **1206**, limiting amplifier **1208**, driver amplifier **1210**, and filter **1212**.

In this illustrative example, printed wiring board **1201** is an example of one implementation of substantially planar insulating structure **370** in FIG. **3**. Printed wiring board **1201** has first surface **1214** and second surface **1216**. As depicted, optical detector **1202** is located in housing **1218**. Housing **1218** is located on first surface **1214** of printed wiring board **1201**. Further, housing **1218** may be connected to first surface **1214** using, for example, a thermally conductive epoxy. In this manner, optical detector **1202** is connected to first surface **1214** of printed wiring board **1201**.

As depicted, transimpedance amplifier **1206** and limiting amplifier **1208** are connected to optical detector **1202**. In this illustrative example, transimpedance amplifier **1206** and limiting amplifier **1208** are connected to second surface **1216** of printed wiring board **1201**.

Light emitting diode **1204** is connected to driver amplifier **1210**. As depicted, both light emitting diode **804** and driver amplifier **810** are located on first surface **1214** of printed wiring board **801**. Light emitting diode **1204** is also located in housing **1218**.

In this advantageous embodiment, filter **1212** is used in place of a splitter, such as plastic optical fiber splitter **812** in FIG. **8**. Filter **1212** is an example of one implementation of filter **361** in FIG. **3**. Filter **1212** transmits one wavelength and reflects another wavelength. For example, filter **1212** can be configured to transmit green wavelengths and reflect red wavelengths. Alternatively, filter **1212** can be configured to transmit red wavelength and reflect green wavelength.

In these illustrative examples, filter **1212** is configured to reflect a signal received on plastic optical fiber **1220** having a range of wavelengths to optical detector **1202**. Filter **1212** is

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further configured to allow a signal having a range of wavelengths from light emitting diode **1204** to be received on plastic optical fiber **1220**.

Having both optical detector **1202** and light emitting diode **1204** located in housing **1218** allows surface space savings for transceiver **1200**. For example, the configuration of transceiver **1200** may have dimensions that are smaller than the configuration of transceiver **800** in FIGS. **8-11**. In FIG. **12**, transceiver **1200** may have dimensions of about 0.53 inches in width, about 1.4 inches in length, and about 0.45 inches in height.

With reference now to FIG. **13**, an illustration of a top view of a transceiver is depicted in accordance with an advantageous embodiment. In this illustrative example, transceiver **1200** is seen from first surface **1214**.

With reference now to FIG. **14**, an illustration of a bottom view of a transceiver is depicted in accordance with an advantageous embodiment. In this illustrative example, transceiver **1200** is seen from second surface **1216**.

The processes, steps, and structures described below in FIGS. **15-21** do not form a complete process flow for manufacturing integrated circuits. The present invention can be practiced in conjunction with integrated circuit fabrication techniques currently used in the art, and only so much of the commonly practiced process steps are included as necessary for an understanding of the present disclosure. The figures represent cross sections of a portion of an integrated circuit during fabrication and are not drawn to scale, but instead are drawn so as to illustrate features in the one or more of the different advantageous embodiments.

With reference now to FIG. **15**, an illustration of a cross-sectional view of a portion of an integrated circuit during fabrication is depicted in which an advantageous embodiment may be implemented. Integrated circuit **1500** may be an example of one implementation of optical detector **400** in FIG. **4** during a fabrication process. In this example, integrated circuit **1500** includes substrate **1502**, intrinsic region **1504** and insulation layer **1506**.

In these illustrative examples, substrate **1502** is a semiconductor material having a type of conductivity. Substrate **1502** may be an n-type substrate or a p-type substrate. In this example, substrate **1502** may be used as a material upon which to form an optical detector, such as optical detector **400** in FIG. **4**.

Intrinsic region **1504** is formed on substrate **1502**. In this example, intrinsic region **1504** is formed with a thickness of about 1 micron or greater. Intrinsic region **1504** may be deposited or grown onto substrate **1502** using epitaxial growth processes. Epitaxial growth is a process in which a layer or film of a semiconductor material is deposited on the surface of a substrate. The epitaxial growth process may be used to control the dopant concentration, thickness, and composition of the layer or film deposited.

For example, intrinsic region **1504** may take the form of a single crystal silicon semiconductor layer. The silicon in intrinsic region **1504** may have a dopant concentration substantially equal to or less than about 1×10^{15} dopant atoms per cubic centimeter.

Insulation layer **1506** is formed on intrinsic region **1504**. Insulation layer **1506** can be formed by a process such as oxidation. Oxidation is a process of heating a silicon layer to a temperature of about 1000 to about 1200 degrees Celsius in the presence of oxygen. Oxidation results in a layer of silicon dioxide insulating material being formed on the surface of the silicon layer.

With reference now to FIG. **16**, an illustration of a cross-sectional view of a portion of an integrated circuit during

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fabrication is depicted in which an advantageous embodiment may be implemented. Integrated circuit 1500 has area 1600 added to the configuration of integrated circuit 1500 in FIG. 15. Area 1600 is formed in intrinsic region 1504.

In these illustrative examples, area 1600 may be formed into a ring shape surrounding a portion of surface 1604 of intrinsic region 1504. In other advantageous embodiments, area 1600 may be formed to only partially surround a portion of surface 1604. In still other advantageous embodiments, area 1600 may be formed into any number of shapes such as, for example, without limitation, a square shape, a rectangle shape, an oval shape, a donut shape, a horseshoe shape, or some other suitable shape.

Area 1600 is comprised of a semiconductor material and has a type of conductivity opposite of intrinsic region 1504. For example, area 1600 is a p-type semiconductor material. Area 1600 may also be an n-type semiconductor material. Area 1600 is an example of one implementation of area 438 in FIG. 4.

Area 1600 can be formed in intrinsic region 1504 by removing portions 1602 from insulation layer 1506. Portions 1602 may be removed using photolithographic masks to define portions 1602 to be etched away. Etching is a process of removing portions of a semiconductor or dielectric material using chemicals to remove the material with the aid of photoresist masking steps. Then, area 1600 may be formed by diffusing dopants into surface 1604 of intrinsic region 1504. For example, area 1600 can be formed by diffusing zinc into an area of intrinsic region 1504. Diffusion is the adding of dopants by heating a surface of a semiconductor material in the presence of the dopant. Area 1600 can also be formed using ion implantation processes. Ion implementation is the process of bombarding a semiconductor with atoms from a particle accelerator.

With reference now to FIG. 17, an illustration of a cross-sectional view of a portion of an integrated circuit during fabrication is depicted in which an advantageous embodiment may be implemented. Integrated circuit 1500 has metal layer 1700 added to the configuration of integrated circuit 1500 in FIG. 16. As depicted, metal layer 1700 is formed on intrinsic region 1504.

Metal layer 1700 is formed on a portion of the surface of intrinsic layer 1504. Metal layer 1700 is an example of one implementation of first metal layer 408 in FIG. 4.

Metal layer 1700 can be formed on intrinsic region 1504 by removing portions from insulation layer 1506. Portions of insulation layer 1506 may be removed using photolithographic masks to define a portion of surface 1604 of intrinsic region 1504 for metal layer 1700 to be deposited upon. Metal layer 1700 can then be deposited onto the surface of the intrinsic layer through evaporation. Evaporation is the process of heating a metal to its boiling point in a vacuum. Using evaporation, metal layer 1700 can be deposited to thickness of about 50 angstroms to about 100 angstroms.

With reference now to FIG. 18, an illustration of a cross-sectional view of a portion of an integrated circuit is depicted in which an advantageous embodiment may be implemented. In this illustrative example, integrated circuit 1500 takes the form of optical detector 1800.

In this illustrative example, optical detector 1800 has first metal contact 1802, second metal contact 1804, and layer of material 1806 added to the configuration of integrated circuit 1500 in FIG. 17.

First metal contact 1802 is formed on surface 1822 of substrate 1502. First metal contact 1802 may be deposited on substrate 1502 through evaporation, as discussed above.

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Layer of material 1806 is formed on a portion of metal layer 1700. For example, layer of material 1806 may be an antireflective coating. In this illustrative example, layer of material 1806 may be coupled to an optical fiber to receive an optical signal, such as first optical signal 324 in FIG. 3. For example, an antireflective coating may be formed by depositing materials by sputtering or plasma deposition processes.

Second metal contact 1804 is formed above insulation layer 1506 and contacts a portion of metal layer 1700. Second metal contact 1804 may be deposited through evaporation and/or plating techniques. Additionally photolithographic masks and/or etching may be used to define areas for second metal contact 1804 to be deposited. For example, second metal contact 1804 is deposited on insulation layer 1506 and contacts a portion of metal layer 1700.

Area 1600 extends from surface 1604 of intrinsic region 1504 into intrinsic region 1504. Area 1600 also surrounds the portion of surface 1604 in contact with metal layer 1700.

Plurality of photons 1808 travel through plastic optical fiber 1810 and are received by optical detector 1800. Layer of material 1806 reduces a reflection of plurality of photons 1808 from metal layer 1700. Plurality of photons 1808 pass through metal layer 1700 and enter into intrinsic region 1504. The absorption of plurality of photons 1808 into intrinsic region 1504 pushes electrons in intrinsic region 1504 downwards into substrate 1502 generating an electrical signal.

Area 1600 surrounds the area of intrinsic region 1504 where the majority of plurality of photons 1808 enter intrinsic region 1504. Area 1600 reduces flow of electrons along surface 1604. Electrons moving along surface 1604 may be referred to as excess dark current which is a source of shot noise in optical detector 1800. Instead of flowing along surface 1604, area 1600 increases a flow of electrons toward substrate 1502 to generate an electrical signal. As a result, an electrical signal is generated with greater sensitivity to an input of plurality of photons 1808.

With reference now to FIG. 19, an illustration of a cross-sectional view of a portion of an integrated circuit during fabrication is depicted in which an advantageous embodiment may be implemented. In this illustrative example, integrated circuit 1500 has layer 1900 added to the configuration of integrated circuit 1500 in FIG. 15.

As depicted, layer 1900 is formed on intrinsic region 1504. Layer 1900 can be formed by the process of etching away portions of the surface of intrinsic region 1504 and then depositing an insulation layer on the remaining or etch surface of intrinsic region 1504. Layer 1900 may be a passivation layer. A passivation layer is used to prevent the etched surface from being unprotected with atoms exposed. Layer 1900 protects the etched surface by bonding with the exposed atoms of surface of intrinsic region 1504, once the surface of intrinsic region 1504 has been etched. Etching is a process of removing portions of a surface of a semiconductor material using chemicals removal with the aid of photoresist masking steps. For example, layer 1900 may be a layer of silicon dioxide to passivate the etched silicon surface of intrinsic region 1504. The etching to form layer 1900 forms raised portion 1902 of the surface of intrinsic region 1504. Raised portion 1902 is an example of one implementation of raised portion 440 in FIG. 4.

With reference now to FIG. 20, an illustration of a cross-sectional view of a portion of an integrated circuit during fabrication is depicted in which an advantageous embodiment may be implemented. In this illustrative example, integrated circuit 1500 has metal layer 2000 added to the configuration of integrated circuit 1500 in FIG. 15. Metal layer 2000 is formed on intrinsic region 1504.

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Metal layer **2000** is formed on a portion of the surface of intrinsic layer **1504**. Metal layer **2000** is an example of one implementation of first metal layer **408** in FIG. **4**.

Metal layer **2000** can be formed on intrinsic region **1504** by removing portions from layer **1900**. Portions of layer **1900** may be removed using photolithographic masks to define a portion of surface **2002** of intrinsic region **1504** for metal layer **2000** to be deposited upon. Metal layer **2000** may then be deposited onto intrinsic layer **1504** through evaporation techniques, as discussed above. Using evaporation techniques, metal layer **2000** can be deposited to thickness of about 50 angstroms to about 100 angstroms.

With reference now to FIG. **21**, an illustration of a cross-sectional view of a portion of an integrated circuit is depicted in which an advantageous embodiment may be implemented. In this illustrative example, integrated circuit **1500** takes the form of optical detector **2100**. As depicted, optical detector **2100** has first metal contact **2102**, second metal contact **2104** and layer of material **2106** added to the configuration of integrated circuit **1500** in FIG. **20**.

In this illustrative example, first metal contact **2102**, second metal contact **2104** and layer of material **2106** may be formed as depicted by first metal contact **1802**, second metal contact **1804**, and layer of material **1806** in FIG. **18**.

Plurality of photons **2108** travel through plastic optical fiber **2109** and are received by optical detector **2100**. Plurality of photons **2108** pass through metal layer **2000** and enter into intrinsic region **1504**. The absorption of plurality of photons **2108** into intrinsic region **1504** pushes electrons in intrinsic region **1504** downwards into substrate **1502** generating an electrical signal.

Raised portion **1902** reduces thickness **2110** of intrinsic region **1504**. The thickness of intrinsic region **1504** directly beneath metal layer **2000** is larger than thickness **2110**. Layer **1900** reduces the flow of electrons along surface **2112**. Layer **1900** may provide less area present outside the portion of intrinsic region **1504** directly below metal layer **2000**. Less area for electrons to flow along surface **2112** increases a flow of electrons toward substrate **1502**. As a result, an electrical signal is generated with greater sensitivity to an input of plurality of photons **2108**.

The illustrations provided in FIGS. **15-21** are not meant to imply physical or architectural limitations to the manner in which different advantageous embodiments can be implemented. For example, the sizes and dimensions in FIG. **15-21** may be increased or decreased depending on implementation. As another example, intrinsic region **1504** in FIG. **15** may be grown to levels of less than one micron for decreased size of the overall chip. Additionally, any type of semiconductor material may be used in the semiconductor device. For example, without limitation, intrinsic region **1504** and/or substrate **1502** may be comprised of silicon, germanium, gallium arsenide, indium gallium arsenide, indium phosphide, and/or any other suitable semiconductor material.

With reference now to FIG. **22**, an illustration of a flow-chart of a process for processing optical signals is depicted in accordance with an advantageous embodiment. The process illustrated in FIG. **22** may be implemented in an optical signal environment, such as optical signal environment **300** in FIG. **3**.

The process begins by receiving a first optical signal from an optical fiber at an input surface of an optical detector (operation **2200**). In operation **2200**, the input surface of the optical detector may have a diameter that is substantially equal to a diameter of a core in the optical fiber. By having these two diameters be substantially equal, signal distortion and capacitance may be reduced.

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The process sends an electrical signal from the optical detector to a two stage amplifier system connected to an output of the optical detector (operation **2202**), with the process terminating thereafter. In operation **2202**, the optical detector and the two stage amplifier system are connected to the output of the optical detector from an optical receiver. The optical receiver has a sensitivity having a value substantially equal to or less than about -32 decibel milliwatts.

With reference now to FIG. **23**, an illustration of a flow-chart of a process for processing optical signals is depicted in accordance with an advantageous embodiment. The process illustrated in FIG. **23** may be implemented in an optical signal environment, such as optical signal environment **300** in FIG. **3**.

The process begins by sending a first optical signal to an optical detector in response to receiving the first optical signal at a first port of an optical splitter (operation **2300**). In operation **2300**, the optical splitter may have a second port coupled to the optical detector. The optical splitter may send the first optical signal from the first port to the second port.

Thereafter, the process receives the first optical signal from an optical fiber at an input surface of the optical detector (operation **2302**). In operation **2302** the input surface of the optical detector may have a diameter that is substantially equal to a diameter of a core in the plastic optical fiber. By having these two diameters be substantially equal, signal distortion and capacitance may be reduced.

The process sends an electrical signal from the optical detector to a two stage amplifier system connected to an output of the optical detector (operation **2304**), with the process terminating thereafter. In operation **2304**, the optical detector and the two stage amplifier system are connected to the output of the optical detector to form an optical receiver. The optical receiver has a sensitivity having a value substantially equal to or less than about -32 decibel milliwatts.

The process then sends a second optical signal to the first port of the optical splitter in response to receiving the second optical signal from an optical transmitter (operation **2306**), with the process terminating thereafter. In operation **2306**, the optical transmitter may be coupled to a third port of the optical splitter. The second optical signal may be generated by a light emitting diode of the optical transmitter.

With reference now to FIG. **24**, an illustration of a flow-chart of a process for forming an optical detector is depicted in accordance with an advantageous embodiment. The process illustrated in FIG. **24** may be implemented in an optical signal environment, such as optical signal environment **400** in FIG. **4**.

The process begins by forming a substrate having a type of conductivity (operation **2400**). In operation **2400**, the substrate may be formed from semiconductor materials. The substrate may have an n-type of conductivity. Thereafter, the process forms an intrinsic region above the substrate having a surface (operation **2402**).

In operation **2402**, the intrinsic region has a surface. The intrinsic region may be formed by growing a layer of semiconductor material on the substrate. The intrinsic region may also be formed by depositing a layer of semiconductor material on the substrate and/or some other suitable methods.

The process then forms a metal layer on a portion of the surface of the intrinsic region (operation **2404**) with the process terminating thereafter. In operation **2404**, the metal layer has a thickness configured to allow a plurality of photons to pass through the metal layer into the intrinsic region and forms a rectifying contact with the intrinsic region. The metal

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layer may be formed by depositing the metal layer on the portion of the surface of the intrinsic region using photolithographic masks.

With reference now to FIG. 25, an illustration of a flowchart of a process for forming an optical detector is depicted in accordance with an advantageous embodiment. The process illustrated in FIG. 25 may be implemented in an optical signal environment, such as optical signal environment 400 in FIG. 4.

The process begins by forming a substrate having a type of conductivity (operation 2500). In operation 2500, the substrate may be formed from semiconductor materials. The substrate may have an n-type of conductivity. The process forms an intrinsic region above the substrate having a surface (operation 2502).

In operation 2502 the intrinsic region has a surface. The intrinsic region may be formed by growing a layer of semiconductor material on the substrate. The intrinsic region may also be formed by depositing a layer of semiconductor material on the substrate and/or some other suitable methods.

Thereafter, the process forms an area that extends from the surface into the intrinsic region having a second type of conductivity (operation 2504). In operation 2504, the area surrounds a portion of the intrinsic region around the metal layer. The area may have a p-type of conductivity. The area may be configured to reduce a current moving across the surface outside of the intrinsic region surrounded by the area. The area may be formed by diffusing zinc into the surface of the intrinsic region. The area may also be formed by implanting ions into the intrinsic region using a particle accelerator.

The process then forms a metal layer on a portion of the surface of the intrinsic region (operation 2506), with the process terminating thereafter. In operation 2506, the metal layer has a thickness configured to allow a plurality of photons to pass through the metal layer into the intrinsic region and forms a rectifying contact with the intrinsic region. The metal layer may be formed by depositing the metal layer on the portion of the surface of the intrinsic region using photolithographic masks.

With reference now to FIG. 26, an illustration of a flowchart of a process for forming an optical detector is depicted in accordance with an advantageous embodiment. The process illustrated in FIG. 26 may be implemented in an optical signal environment, such as optical signal environment 400 in FIG. 4.

The process begins by forming a substrate having a type of conductivity (operation 2600). In operation 2600, the substrate may be formed from semiconductor materials. The substrate may have an n-type of conductivity. The process forms an intrinsic region above the substrate having a surface (operation 2602).

In operation 2602, the intrinsic region has a surface. The intrinsic region may be formed by growing a layer of semiconductor material on the substrate. The intrinsic region may also be formed by depositing a layer of semiconductor material on the substrate and/or some other suitable methods.

Thereafter, the process forms a raised portion of the surface (operation 2604). The raised portion is configured to reduce a current moving across the surface outside of the raised portion. The raised portion may be formed by etching the surface of the intrinsic region.

The process then forms a metal layer on a portion of the surface of the intrinsic region (operation 2606), with the process terminating thereafter. In operation 2606, the metal layer has a thickness configured to allow a plurality of photons to pass through the metal layer into the intrinsic region and form an ohmic contact with the intrinsic region. The

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metal layer may be formed by depositing the metal layer on the portion of the surface of the intrinsic region using photolithographic masks.

The flowcharts and block diagrams in the different depicted embodiments illustrate the architecture, functionality, and operation of some possible implementations of apparatus and methods in different advantageous embodiments. In this regard, each block in the flowcharts or block diagrams may represent a module, segment, function, and/or a portion of an operation or step.

In some alternative implementations, the function or functions noted in the blocks may occur out of the order noted in the figures. For example, in some cases, two blocks shown in succession may be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. Also, other blocks may be added in addition to the illustrated blocks in a flowchart or block diagram.

Thus, the different advantageous embodiments provide a method and apparatus for a transceiver for networks with plastic optical fibers. In one advantageous embodiment, an apparatus comprises an optical transmitter; an optical detector configured to receive optical signals from an optical fiber; an optical splitter having a first port, a second port coupled to the optical detector by the optical fiber, and a third port coupled to the optical transmitter; and a two stage amplifier system connected to an output of the optical detector. An input surface of the optical detector has a diameter that is substantially equal to a diameter of a core in the optical fiber.

The optical detectors depicted in the different advantageous embodiments increase a level of sensitivity for a transceiver for networks with plastic optical fibers. For example, the configuration of the diameter of the input surface of the optical detector reduces signal distortion and reduces capacitance. The raised portions and/or areas of the intrinsic region of the optical detectors increase a flow of electrons toward the substrate. This increased flow causes an output signal to be produced from the optical detector with greater sensitivity to the input signal received. Further, the configuration of the transceiver increases surface space savings and reduces bending of optical fibers.

The description of the different advantageous embodiments has been presented for purposes of illustration and description, and it is not intended to be exhaustive or limited to the embodiments in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. Further, different advantageous embodiments may provide different advantages as compared to other advantageous embodiments. The embodiment or embodiments selected are chosen and described in order to best explain the principles of the embodiments, the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use contemplated.

What is claimed is:

1. An optical detector comprising:

a substrate having a type of conductivity;

an intrinsic region above the substrate, the intrinsic region having a surface; and

a first metal layer on a portion of the surface of the intrinsic region, the first metal layer having a thickness from about 50 angstroms to about 100 angstroms, and the thickness being configured to allow a plurality of photons to pass through the first metal layer into the intrinsic region and form a rectifying contact with the intrinsic region, and wherein the substrate, the intrinsic region, and the first metal layer form a Schottky barrier diode.

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2. The optical detector of claim 1, wherein the type of conductivity is a first type of conductivity and further comprising:

an area having a second type of conductivity in which the area extends from the surface into the intrinsic region, wherein the area surrounds the portion of the surface of the intrinsic region around the first metal layer and is configured to reduce a current moving across the surface outside of the intrinsic region surrounded by the area.

3. The optical detector of claim 2, wherein the first type of conductivity is an n-type and the second type of conductivity is a p-type.

4. The optical detector of claim 1, further comprising:

a fourth layer of a material on the first metal layer, wherein the material is configured to reduce reflection of the plurality of photons that hit the material.

5. The optical detector of claim 4, wherein the fourth layer of the material is an antireflective coating.

6. The optical detector of claim 1, further comprising:

a second metal contact layer in contact with a surface of the substrate, wherein the surface of the substrate is opposite to the surface of the intrinsic region.

7. The optical detector of claim 1, further comprising:

a third metal contact layer, wherein the third metal contact layer contacts a portion of a surface of the first metal layer.

8. The optical detector of claim 1, wherein the first metal layer comprises a material selected from the group consisting of gold and indium-tin-oxide.

9. The optical detector of claim 1, wherein the intrinsic region consists essentially of a silicon that is pure but includes a concentration of dopants in the intrinsic region is equal to or less than about 1×10^{15} dopant atoms per cubic centimeter.

10. An optical detector comprising:

a substrate having an n-type conductivity;

an intrinsic region above the substrate, the intrinsic region having a surface; and

a first metal layer on a portion of the surface of the intrinsic region, the first metal layer having a thickness from about 50 angstroms to about 100 angstroms, and the thickness being configured to allow a plurality of photons to pass through the first metal layer into the intrinsic region and form a rectifying contact with the intrinsic region; and

an area having a p-type conductivity in which the area extends from the surface into the intrinsic region, the area surrounding the portion of the surface of the intrinsic region around the first metal layer and being configured to reduce a current moving across the surface outside of the intrinsic region surrounded by the area.

11. The optical detector of claim 10, further comprising: a fourth layer of a material on the first metal layer, wherein the material is configured to reduce reflection of the plurality of photons that hit the material.

12. The optical detector of claim 11, wherein the fourth layer of the material is an antireflective coating.

13. The optical detector of claim 10, further comprising: a second metal contact layer in contact with a surface of the substrate, wherein the surface of the substrate is opposite to the surface of the intrinsic region.

14. The optical detector of claim 10, further comprising: a third metal contact layer, wherein the third metal contact layer contacts a portion of a surface of the first metal layer.

15. The optical detector of claim 10, wherein the substrate, the intrinsic region, and the first metal layer form a Schottky barrier diode.

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16. The optical detector of claim 10, wherein the first metal layer comprises a material selected from the group consisting of gold and indium-tin-oxide.

17. The optical detector of claim 10, wherein the intrinsic region consists essentially of a silicon that is pure but includes a concentration of dopants in the intrinsic region is equal to or less than about 1×10^{15} dopant atoms per cubic centimeter.

18. The optical detector of claim 10, wherein the intrinsic region has a thickness of greater than about 1 micron.

19. A method for forming an optical detector, the method comprising:

forming a substrate having a type of conductivity;

forming an intrinsic region above the substrate, the intrinsic region having a surface; and

forming a first metal layer on a portion of the surface of the intrinsic region, the first metal layer having a thickness from about 50 angstroms to about 100 angstroms, and the thickness being configured to allow a plurality of photons to pass through the first metal layer into the intrinsic region and form a rectifying contact with the intrinsic region, and wherein forming the substrate, forming the intrinsic region, and forming the first metal layer combine to form a Schottky barrier diode.

20. The method of claim 19, wherein the step of forming the intrinsic region above the substrate comprises:

growing a fifth layer of semiconductor material above the substrate to form the intrinsic region.

21. The method of claim 19, wherein the step of forming the intrinsic region above the substrate comprises:

depositing a sixth layer of semiconductor material above the substrate to form the intrinsic region.

22. The method of claim 19, wherein the step of forming the first metal layer on the portion of the surface of the intrinsic region comprises:

forming the first metal layer on the portion of the surface of the intrinsic region by depositing the first metal layer on the portion of the surface of the intrinsic region using photolithographic masks.

23. The method of claim 19, wherein the type of conductivity is a first type of conductivity and further comprising:

forming an area that extends from the surface into the intrinsic region having a second type of conductivity, wherein the area surrounds the portion of the intrinsic region around the first metal layer and wherein configuring the area to reduce a current moving across the surface outside of the intrinsic region surrounded by the area.

24. The method of claim 23, wherein the step of forming the area that extends from the surface into the intrinsic region having the second type of conductivity comprises:

forming the area having the second type of conductivity by zinc diffusion.

25. The method of claim 23, wherein the step of forming the area that extends from the surface into the intrinsic region having the second type of conductivity comprises: forming the area that extends from the surface into the intrinsic region having the second type of conductivity, wherein first type of conductivity is an n-type and the second type of conductivity is a p-type.

26. The method of claim 19, further comprising:

forming a fourth layer of a material on the first metal layer, wherein the material is configured to reduce reflection of the plurality of photons that hit the material.

27. The method of claim 26, wherein the step of forming the fourth layer of a material on the first metal layer further comprises the fourth layer of the material being an antireflective coating.

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28. The method of claim 19, further comprising:
forming a second metal contact layer in contact with a
surface of the substrate, wherein the surface of the sub-
strate is positioned opposite to the surface of the intrinsic
region.

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29. The method of claim 19, further comprising:
forming a third metal contact layer, wherein the third metal
contact layer contacts a portion of a surface of the first
metal layer.

30. The method of claim 19, wherein the step of forming 10
the first metal layer on the portion of the surface of the
intrinsic region further comprises the first metal layer being
comprised of a material selected from the group consisting of
gold and indium-tin-oxide.

31. The optical detector of claim 1, wherein the optical 15
detector is comprised by an apparatus and the apparatus fur-
ther comprises a plastic optical fiber.

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